UDC 621.313

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MATHEMATICAL DESCRIPTION OF THE ASYNCHRONOUS TWO-MACHINE AGGREGATE WITH A ROTATING INDUCTOR

Abstract. It was developed mathematical description of the asynchronous two-machine aggregate with a rotating inductor, that was made as an initial stage of development of its full-fledged simulation model. The use of this class of electric machines is relevant in high-speed electric drives, without using frequency converter or raising gearbox, as well as the ability to distribute different speed motion on two shafts.

Key words: asynchronous machine, two-machine aggregate, mathematical description, rotating inductor.

The distinctive properties of two-machine aggregate with a rotary inductor, as a separate class of electric machines, is to obtain a high speed of the asynchronous electric drive with the possibility of its regulation within wide limits without the use of the frequency converter, as well as the possibility of obtaining different power and speed of rotation on two shafts without the use of a reducer or a differential, ensuring a smooth unrestricted start of the electric drive, etc.

In order to clarify the construction of structural elements in the design and definition of the features of the operation of this electrical machine, there is a need to develop mathematical model. The following design was chosen for the study.

The electric motor (Fig. 1) consists of a case 1 in which the stator 2 is secured with a three-phase winding 3. A shaft 4 secured a high-speed rotor 5 with a short-circuited winding 6. A rotating inductor 7 with a three-phase winding 8 and short-winding 9 is placed concentrically relatively to the stator 2 and the rotor 5. Power supply is fed to the winding 3 of the stator 2 through the terminal box 14, and on the winding 8 of the moving inductor 7, through the brush knot 15 and the contact rings 16, which are fixed to the hollow shaft 12. Detailed design is given in [1].

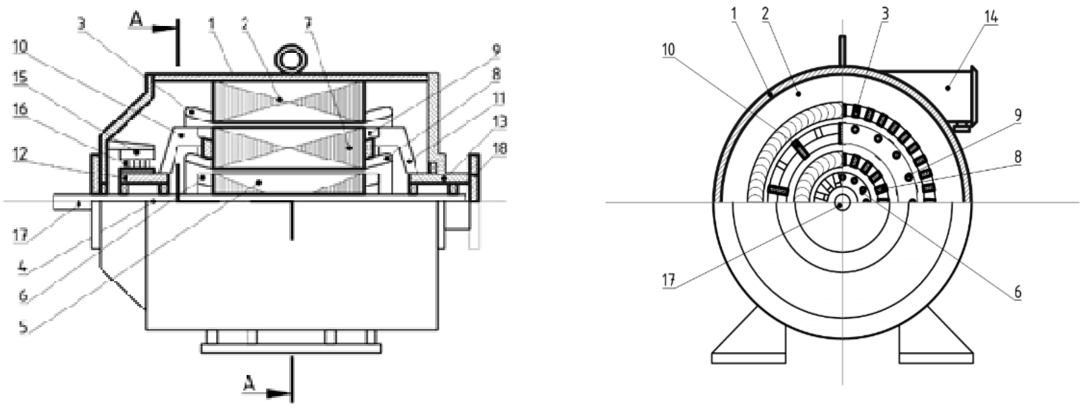

Fig. 1. Construction of a two-machine asynchronous aggregate with a rotating inductor.

When voltage supply to the stator winding, a synchronous rotating magnetic field rotating at a speed $w_1 = 2pf_м / p_1$ is formed. The rotating magnetic field induces currents in the short-circuited winding of a rotating inductor and leads it to rotate with angular velocity $w_2 = w_1(1 - S_1)$, where S_1 is a slip of the primary machine. At the same time three-phase supply voltage is also fed to the three-phase winding of a moving inductor through the ring-brush mechanism. The magnetic field of a moving inductor relatively to a stationary stator rotates at an angular velocity $w_3 = w_2 + w_c$, where $w_c = 2pf_м / p_2$ is synchronous velocity, and induces short-circuited currents in the rotor winding. This, in turn, leads to the asynchronous moment of rotation of the rotor with angular velocity $w_4 = w_3(1 - S_2)$, where S_2 is the slip of a secondary machine. As a result, we get the value of the angular speed of the rotor in the form:

$$w_4 = 2pf(1 - S_2)[(1 - S_1)/p_1 + 1/p_2], \qquad (1)$$

where $p_{1,2}$ – the number of poles of the primary and secondary machines; $S_{1,2}$ – slip of the primary and secondary machine; f – power supply frequency.

The description of the aggregate is based on the mathematical description of the asynchronous motor by the method of depicting vectors [2,3].

The work of the primary and secondary machines can be described by the following system of equations:

$$\begin{cases} \vec{U}_1 = R_1\vec{i}_1 + \dfrac{d\vec{y}_1}{dt} \\ \vec{U}_2 = R_2\vec{i}_2 + \dfrac{d\vec{y}_2}{dt} \\ \vec{y}_1 = L_1\vec{i}_1 + L_{m1}\vec{i}_2 \\ \vec{y}_2 = L_2\vec{i}_2 + L_{m1}\vec{i}_1 \\ \vec{M}_1 = \dfrac{3}{2}p_1 Mod(\vec{y}_1\vec{i}_1) \\ J_1\dfrac{d\vec{w}_2}{dt} = \vec{M}_1 - \vec{M}_2 \end{cases} \qquad \begin{cases} \vec{U}_3 = R_3\vec{i}_3 + \dfrac{d\vec{y}_3}{dt} \\ \vec{U}_4 = R_4\vec{i}_4 + \dfrac{d\vec{y}_4}{dt} \\ \vec{y}_3 = L_3\vec{i}_3 + L_{m2}\vec{i}_4 \\ \vec{y}_4 = L_4\vec{i}_4 + L_{m2}\vec{i}_3 \\ \vec{M}_2 = \dfrac{3}{2}p_2 Mod(\vec{y}_3\vec{i}_3) \\ J_2\dfrac{d\vec{w}_4}{dt} = \vec{M}_2 - \vec{M}_c \end{cases}, \qquad (2)$$

where $\vec{U}, R, \vec{i}, \vec{y}, L$ are voltage, resistance, current, magnetic flux, and inductance of the winding of the stator (1), the short-circuit winding of the rotating inductor (2), the three-phase winding of the rotating inductor (3), the short-circuit winding of the rotor (4); $\vec{M}, J, L_m$ are the electromagnetic torque, the moment of inertia, the mutual inductance of the primary (1) and secondary (2) machines of the two-machine aggregate, and $\vec{M}_c$ – the static torque of the load on the shaft of the rotor.

Thus, in this mathematical description, a connection between two machines is provided at the speed and torque, since the electromagnetic torque produced by the rotating inductor is simultaneously the load for the primary machine.

This mathematical description is the initial stage of development of a complete imitative model of asynchronous two-machine aggregate with a rotating inductor.

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